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The Evolution of C2

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14. ABSTRACT
Military, intelligence and industry officials are universal in their praise for autonomous systems. These systems have been used extensively in the conflicts in Iraq and Afghanistan and are already creating strategic, operational, and tactical possibilities that did not exist a decade ago. However, while these autonomous systems are of enormous value today and are evolving to deliver better capabilities to the warfighter, it is their promise for the future that causes the most excitement. These leading edge ? and indeed, revolutionary, systems ? offer unprecedented potential to be the game-changers that will provide tomorrow?s military with heretofore unimagined capability. But for these autonomous systems to reach their full potential, important C4ISR considerations must be addressed. The science of building unmanned air, ground, surface, and underwater vehicles is well-advanced. But the costs of military manpower mandate we move beyond the ?one-man, one-joystick, one-vehicle? paradigm that has existed during the past decades of autonomous systems development. We will present examples of ground-breaking work going on in the DoD laboratory community that is paving the way for a completely new paradigm ? multiple autonomous systems controlled by one operator ? providing their own command and control and self-synchronization as the ?way ahead? for future autonomous systems.

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However, while these autonomous systems are of enormous value today and are *evolving* to deliver better capabilities to the warfighter, it is their promise for the future that causes the most excitement. These leading edge – and indeed, revolutionary, systems – offer unprecedented potential to be the game-changers that will provide tomorrow's military with heretofore unimagined capability.

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Perspective

“My view is that technology sets the parameters of the possible; it creates the potential for a military revolution.”[1]

Max Boot
War Made New

The Navy has a rich history of concept generation, concept development, technology innovation and insertion, and of embracing both evolutionary and revolutionary changes in technology that have altered the face of naval warfare. That tradition continues today. As noted by a former Chief of Naval Research, “The Navy/Marine Corps of today and tomorrow are and will remain critically enabled by the power of science and technology put to work for our Sailors and Marines.”[2]

The U.S. Navy’s innovative technology development builds on over 500 years of naval technology that has changed the course of battle, and in many cases, of history. From the superior oceangoing sailing ships and heavy cannon technology that helped Elizabeth I defeat the Spanish Armada, to the Civil War-inspired development of ironclad ships in the mid-1800s, to Japan’s ability to better harness the technologies in the transition from sailing ships firing solid cannonballs to turbine-powered dreadnoughts spewing high-explosive shells, to the World War II transition from battleships to aircraft carriers as the principal ship-of-the-line for first class navies; one navy’s ability to defeat the other has often depended on who inserted the best technology the fastest and most effectively.[3]

Others have pointed out how much technology impacts not just the outcome of battles, but the fate of nations. As Bruce Berkowitz notes in *The New Face of War*, “Recent experience suggests that the right technology, used intelligently, makes sheer numbers irrelevant. The tipping point was the Gulf War in 1991. When the war was over, the United States and its coalition partners had lost just 240 people. Iraq suffered about 10,000 battle deaths, although no one will ever really be sure. The difference was that the Americans could see at night, drive through the featureless desert without getting lost, and put a single smart bomb on target with a 90 percent probability.”[4]

However, the link between the invention of a new technology and its impact on warfare is never assured. What has proven crucial has been how aggressively nations develop, test, improve and

field these technologies as weapons of war. This is well recognized within the U.S. intelligence and defense communities. In *Global Trends 2025*, the Director of National Intelligence and the National Intelligence Council address the importance of shepherding new technologies to the point where they transition to the end-users, noting; "The pace of technological innovation will be key. Major technologies historically have had an 'adoption lag.'"[5]

The U.S. military understands the profound impact innovation and technology have on the future of warfare, the need for continuous technological experimentation and insertion, and the "unknown unknowns" regarding what future technologies will be needed for America's military decades hence. One of the U.S. military's most forward-looking publications – and the one that under-girds the entire family of Joint publications – the *Joint Operating Environment 2010*, puts the issue of technological uncertainty in stark terms by describing the astounding changes in just the last quarter-century:

> One might also note how much the economic and technological landscapes outside of the military had changed … On the technological side, the Internet existed only in the Department of Defense, and its economic and communications possibilities and implications for the civilian world were not yet apparent. Cellular phones came equipped with briefcases and shoulder straps and only worked in select urban areas. Personal computers were beginning to come into widespread use, but their reliability was terrible. Microsoft was just emerging from Bill Gates' garage, while Google existed only in the wilder writings of science fiction writers. In other words, the revolution in information and communications technologies, taken for granted today, was largely unimaginable in 1983. [6]

One of the reasons the U.S. Navy is the most powerful Navy ever fielded, and, according to Secretary of Defense Robert Gates, "larger than the next 13 navies combined,"[7] has been the Navy's support for scientific and engineering-development efforts. Such efforts have ranged from the Navy's support of the optical research of Lieutenant Albert Michelson in the early 1900s, to support for Thomas Edison's experiments, to research into the physical understanding of long-range radar, to the earliest feasibility investigations of nuclear submarine propulsion, to today's support of a wide-ranging portfolio of science and technology, research and development, engineering feasibility, and test and evaluation.[8]

For the U.S. Navy today, the importance of technology is recognized in the highest level governing documents, beginning with the Navy's new maritime strategy, *A Cooperative Strategy for 21st Century Seapower*, which notes:

> Proliferation of weapons technology and information has increased the capacity of nation-states and transnational actors to challenge maritime access…Asymmetric

> use of technology will pose a range of threats for the United States and its partners.[9]

In today's military – and especially in the U.S. Navy – some of the most advanced technological developments are focused on autonomous systems. Autonomous systems are ushering in a new "revolution in naval affairs" that is as dramatic as any prior revolutions. The potential and enormous promise these technologies provide is indeed breathtaking. The Department of Defense *FY2009-2034 Unmanned Systems Integrated Roadmap* provides a perspective on the future of autonomous systems:

> The vision of the DoD is that unmanned systems will provide flexible options across operating domains, enabling the warfighter's execution of assigned missions. Unmanned systems will be integrated across warfare domains and with manned systems, providing the Joint Force Commander (JFC) with decisive capabilities.[10]

The U.S. Navy has been on the cutting edge in the development of autonomous aerial systems, and these systems are not only changing the way the Navy fights on and from the sea *today*, but are already changing the Navy's doctrine, tactics, techniques and procedures and how the Navy will fight in the *future*. Now, concurrent development of a number of autonomous maritime systems is offering that same promise to usher in revolutionary change in naval warfighting. While this journey has not been going on as long as that of autonomous aerial systems, the promise is just as great, if not greater; as the Department of Defense *FY2009-2034 Unmanned Systems Integrated Roadmap* notes, "Unmanned maritime vehicles (UMVs) present new opportunities to augment our naval forces and maintain maritime superiority around the world."[11]

However, the challenge to achieving game-changing breakthroughs in autonomous air, ground, and maritime vehicles is for the U.S. Navy and the Department of Defense to look beyond what the *FY2009-2034 Unmanned Systems Integrated Roadmap* suggests these systems can do to "augment naval and other military forces." The Navy and DoD must grasp the opportunity to conceive, design, develop, test and field these systems with their ability to change the face of naval warfare firmly in mind. In other words, we must place "big bets" on autonomous systems in order to usher in the true revolution in naval affairs these systems can – and will – deliver.

Autonomous Systems – Technology Enabling and Leading Strategy

"In reality…the categories of warfare are blurring and no longer fit into neat, tidy boxes. One can expect to see more tools and tactics of destruction – from the sophisticated to the simple – being employed simultaneously in hybrid and more complex forms of warfare."[12]

Secretary of Defense the Honorable Robert Gates
"A Balanced Strategy: Reprogramming the Pentagon for a New Age"
Foreign Affairs
January/February 2009

Dramatic changes in the nature of warfare have ushered in the new term "hybrid warfare," which defines the challenges the Joint Force and the Navy-after-Next will face over the next decade. Secretary of Defense Robert Gates popularized this term in his article in *Foreign Affairs*, as he built upon the work of civilian and uniformed military strategists and policy makers.[13]

This hybrid warfare environment changes the focus of the U.S. military from having to deal solely with the exigencies of overseas contingency operations or take on the task of somehow preparing for major combat operations against an unnamed peer competitor on some distant horizon, to dealing with both irregular warfare and traditional threats (read, conventional warfare) *today*. The Secretary of Defense, as well as others in positions to determine how the U.S. military will train, equip, and fight in the near- and mid-term, are defining a re-engineering of the military for the warfighting realities of the next decade.[14]

This change in policy was translated into fiscal reality when Mr. Gates revealed the changes in the Obama Administration's Fiscal Year 2010 budget in a speech in early April 2009.[15] This shift in direction for the Department was presented in more extensive detail a month later, when the detailed Department of Defense Budget was released on May 7, 2009.[16]

However, often lost in the dramatic changes to major weapons systems is a shift in priorities in a wide range of acquisition programs, the net result of which is an increased reliance on autonomous systems for tomorrow's military. In many ways, the Fiscal Year 2011 Obama Administration budget announcement instantiates changes directed by Congress in the Fiscal Year 2007 National Defense Authorization act which, among other provisions, called for the Department of Defense to "establish a policy that gives the DoD guidance on unmanned systems, some key points of which included identifying a preference for unmanned systems in acquisition of new systems."[17]

Military history is replete with examples where changes in strategy spurred new technology development and where new technology led and enabled new strategies. But in much the same way as hybrid warfare blurs previously clear lines determining the nature of warfare, the rapid pace of technological development of today can enable the co-evolution of new strategic opportunities as new technologies emerge.

Nowhere is this more evident than in autonomous systems. The game-changing nature of these systems has been discussed and studied by high-level groups for two decades, and the potential and promise for autonomous systems has never been in question, with the Naval Research Advisory Committee (NRAC) noting in their 2003 report; "The combat potential of UVs (unmanned vehicles) is virtually unlimited…There is no question that the Fleet/Force of the future will be heavily dependent upon UVs."[18]

But while the potential of autonomous systems has always been recognized, the specific ways in which these systems would be used in warfighting was only dimly perceived as recently as a few years ago. However, the exigencies of warfighting have a way of ushering in their own changes. The use of autonomous systems in Operations Enduring Freedom and Iraqi Freedom has spurred the rapid employment and concomitant development of these systems, which would have been beyond the wildest dreams of systems developers before the turn of the century. The explosive growth in the use of autonomous systems in support of today's conflicts has offered a new window on their potential for tomorrow's military. According to the Department of Defense *FY2009-2034 Unmanned Systems Integrated Roadmap*:

> In today's military, unmanned systems are highly desired by combatant commanders (COCOMs) for their versatility and persistence. By performing tasks such as surveillance; signals intelligence (SIGINT); precision target designation; mine detection; and chemical, biological, radiological, nuclear (CBRN) reconnaissance, unmanned systems have made key contributions to the Global War on Terror (GWOT). As of October 2008, coalition unmanned aircraft systems (UAS) (exclusive of hand-launched systems) have flown almost 500,000 flight hours in support of Operations Enduring Freedom and Iraqi Freedom, unmanned ground vehicles (UGVs) have conducted over 30,000 missions, detecting and/or neutralizing over 15,000 improvised explosive devices (IEDs), and unmanned maritime systems (UMSs) have provided security to ports.[19]

But while the *FY2009-2034 Unmanned Systems Integrated Roadmap* "tips the hat" to autonomous maritime systems, these systems still lag behind the far-more-numerous autonomous aircraft systems and autonomous ground systems.[20] The game-changing nature of these systems and the true potential they offer will not be recognized and realized without a concerted effort across the Department of Defense and the Department of the Navy.[21] Therefore, as the Nation's lead maritime service it is especially incumbent on the U.S. Navy to provide the stewardship for ensuring that UMV development keeps pace with the development of all other autonomous systems.

For the Navy, the center of gravity of this effort rests with the Navy staff (N85) and within the Naval Sea Systems Command in the Program Executive Office Littoral & Mine Warfare and, most specifically, in PMS-403, the Unmanned Maritime Systems Program Office.[22] PMS-403 provides direct leadership and stewardship of all UMV programs, including all of the autonomous surface vehicles (USV) and autonomous underwater vehicles (UUV) listed in the Department of Defense *FY2009-2034 Unmanned Systems Integrated Roadmap*. This stewardship will be vital as emerging UMV systems compete for funding in a constrained budget environment.

Evolution or Revolution? Challenges Facing Naval Unmanned Systems

"Today, we are again called to provide visionary leadership. This century's threats are at least as dangerous as and in some ways more complex than those we have confronted in the past…We must use this moment to rebuild our military and prepare it for the missions of the future."[23]

Barack Obama
"Renewing American Leadership"
Foreign Affairs
July/August 2007

What we know, understand, and are already comfortable with regarding autonomous systems will ensure *evolutionary* change in the way the Navy fights on and from the sea. While this will have a positive impact on the Navy, it will not enable these systems to deliver game-changing capabilities for the Navy-after-Next. But with vision, risk-taking, and some "big bets," the Navy can usher in just the revolutionary changes needed to enable the Navy-after-Next to contribute the maximum warfighting and war-winning capabilities to the Joint force.

It is beyond argument that the technological promise of autonomous systems – and especially autonomous maritime systems – is extraordinarily bright. The Navy can count on its S&T and R&D communities, partnered with America's innovative industry, to deliver robust technological solutions. Thus, revolutionary change with autonomous systems is not exclusively a technological challenge, but a cultural one. The Navy has overcome cultural barriers in the past and it can do so again today. But none of this change is on autopilot. It must be created.

The culture, organization, processes and business rules in today's Navy were developed over decades – even centuries – and are unlikely to change dramatically absent a concerted effort from the Navy's senior leadership. This is especially important for autonomous systems writ large, and even more so for autonomous maritime vehicles, because this Navy DNA was developed during a period of limited autonomous systems use and virtually no autonomous maritime system use. Encouragingly, the Navy's leadership took a first step towards this type of

organizational change last year, when the Navy's various unmanned assets were consolidated under the purview of the new N2/N6 directorate. However, it remains to be seen whether or not this step will be followed by others.

This presents immediate barriers to autonomous system development, and especially to manned-autonomous system integration. The challenges are not simple, and organizational bias runs deep. Given that the Navy's current institutional structure has not yet begun to integrate manned and autonomous systems into a coherent framework, true integration will likely involve cultural, doctrinal, personnel and organizational revolutions.

This is not to say these barriers cannot be overcome – only that the Navy must, as an entering argument, recognize and seek to capitalize on the revolutionary capabilities these systems can deliver. While the term "revolution in military affairs" has fallen out of vogue, that is precisely what today's defense and naval leadership must strive for. The 2003 NRAC concluded that, "The combat potential of UVs (unmanned vehicles) is virtually unlimited…There is no question that the Fleet/Force of the future will be heavily dependent upon UVs."[24] This should serve as the underlying principle in the way the Navy approaches the development of all autonomous systems, and UMVs in particular.

The second major challenge to having the Navy "bet" on autonomous maritime systems is the fact that they are so new and their development has been "under the radar" for all but a few naval professionals in the S&T, R&D, requirements, and acquisition communities. This lack of familiarity, coupled with the aforementioned cultural issues, creates a high bar for autonomous maritime systems in particular. The Department of Defense *FY2009-2034 Unmanned Systems Integrated Roadmap* provides a window on the magnitude of this challenge:

> Creation of substantive autonomous systems/platforms within each domain will create resourcing and leadership challenges for all the Services, while challenging their respective Warfighter culture as well…Trust of unmanned systems is still in its infancy in ground and maritime systems… Unmanned systems are still a relatively new concept…As a result; there is a fear of new and unproven technology.[25]

Lastly, one of the ways that autonomous systems writ large – and especially autonomous maritime systems – can usher in revolutionary change in tomorrow's Navy as well as for the Navy-after-Next is in the area of manpower reductions in the Fleet. In fact, this represents the single biggest challenge facing the development and integration of unmanned autonomous systems today. Lessons learned throughout the development process of most autonomous systems – especially autonomous aerial systems – demonstrates that autonomous systems can actually *increase* manning requirements as legions of technicians and operators work with the

system to ensure it works properly and is a welcome addition to whatever warfighting capability and community it is trying to satisfy.

Strong anecdotal evidence suggests that this technical and operational “tail” persists even after the system is in the field; as commanders are just as loathe to have the system fail as its developers were. There is little evidence that reducing manpower as the systems enter service is a vital part of the Key Performance Parameters (KPP) for any of these autonomous systems. This, in turn, introduces a pernicious cycle – as the autonomous systems enter service, they can require more operators, more technicians, and more “tail” than the manned systems they were supposed to supplant.

While this is a less-than-desirable outcome for air and ground autonomous systems, the burden is often masked in the aerial or terrestrial domains. Whether it takes two or four or six or some higher multiple of people to support one autonomous aerial system, in the case of UAVs flying in Iraq that are operated from a base in Nevada, the “tail” is obscured to most. When an operator or technician finishes his or her shift, they return to their home and the support they require is provided there.

The converse is true in the case of autonomous aerial and maritime systems deployed from Navy ships or submarines. Every operator and technician must be embarked in the ship. Each person has a bunk, must be fed, generates administrative and overhead requirements and has quality of life needs that must be met. This, in turn, generates its own manpower needs and adds weight and space to these ships.

In last generation’s Navy with ships with robust manning, there was some flexibility to somehow make this all work. But with today’s – and especially tomorrow’s – optimally manned ships like LCS, DD(X), and CG(X) the manpower challenge is especially acute. And against this backdrop is the indisputable fact that the biggest – and most rapidly rising – cost of ships and systems is manpower, which makes up close to 70% of total operating cost (TOC) of ships. And this massive, manpower-induced, portion of TOC has the full attention of the highest levels of the Navy’s leadership.

The need to reduce manpower on Navy ships as a vehicle for reducing the ship’s Total Ownership Cost (TOC) has been an important imperative for Navy leadership for at least a decade. Successive Chiefs of Naval Operations have made reducing manpower a key part of their annual goals and objectives. The importance of addressing TOC in ship design was perhaps best put by then-CNO Admiral Michael Mullen in an interview in *Government Executive*. In answering a question regarding Navy-wide manpower reductions, Admiral Mullen noted:

> My long term goal is to eliminate the need for jobs and not just keep moving the work around from one part of the workforce to another. In the long run, I am anxious to invest in the technology in order to take the work out. We have a tendency to look at what it takes to get a program out the door. We don't think too much about what the life cycle cost is. It's "Can I build it?" I would like us all to be mindful of what it costs to operate whatever we are building for whatever its life is going to be because I have to pay that bill every single year.[26]

Naval professionals at all levels – and especially those in the acquisition community responsible for the design, building, and life-cycle maintenance of Navy ships and systems, including autonomous systems – are acutely aware of the impact of manpower on the life-cycle costs of these ships and systems. A Naval Sea Systems Command report captured the magnitude of the challenge in this way:

> The largest single component of life-cycle cost for a naval ship is acquiring, training, assigning, and supporting manpower for ship operations, maintenance, and support. The primary benefits of optimized crewing are the significant reduction in ownership costs and improved total system performance.[27]

But the task of reducing manning on Navy ships is daunting. The demands placed on Sailors by Navy ship systems are unique in the breadth of their scope and the depth of their complexity. Navy ship systems employed by the fleet today, and those being designed for tomorrow, make severe demands on the readiness, performance effectiveness, and mental and physical capabilities of personnel who man them. These complex systems are extremely demanding on the senses, motor skills, cognitive skills, and decision-making capabilities of the ship's crew. Add the highly varied nature of the threat; the need to conduct multi-warfare scenarios; and the need to integrate, coordinate and interpret information from multiple sources; and it becomes evident we are rapidly approaching the limits of unaided human capacity and capability.

This is not to say that autonomous aerial and maritime systems will add to this burden. In fact, they decidedly cannot; there is simply no chance the Navy's leadership will accept autonomous systems on Navy ships if they increase the manpower footprint. The introduction of the Firescout UAV to the Fleet is instructive in this regard. Although it was developed in its own Navy/contractor "envelope," when Firescout deploys to the Fleet aboard LCS, that "tether" will be severed and the MH-60 helicopter detachment will operate and maintain this UAV with the net result being no increase in manning.

This is precisely the path UMVs and UAVs deployed from naval ships *must* follow. But with a wide-array of autonomous system developmental efforts, each developmental "tether" will need to be broken and Fleet operators already part of the Ship's Manning Document (SMD) will need to be cross-trained to operate and maintain these autonomous vehicles. While daunting, none of

this is impossible, *if and only if* this commitment to making autonomous systems deployed from naval ships part of the solution – not part of the problem – in reducing manpower on Navy ships is instantiated in the KPP of every autonomous system.

The need to do this is palpable, and at the highest levels of the Navy the need to reduce shipboard manpower is a matter of urgency.[28] The Chief of Naval Operations has been widely quoted in the defense media as giving reduced manpower an extremely high priority, noting in 2008:

> There's no question that crew sizes have got to come down. We, frankly, are not aggressive enough in employing the technologies that allow us to take people off ships. It's largely a cultural thing we've got to break through…and we can do it, I'm confident. In the past, we've had some initiatives underway but they had a hard time taking through. In my tenure I intend to be a little more on the bold side.[29]

But beyond this manpower reduction efforts, the full potential to have autonomous aerial and maritime systems *reduce* overall TOC for Navy ships will not be realized without the concurrent development of the command, control, communications, and computers (C4) technology that enable these autonomous systems to communicate with and be tasked by their operators as well as communicate and self-synchronize with each other. The Department of Defense *FY2009-2034 Unmanned Systems Integrated Roadmap* indicates DoD's goal of fielding transformational capabilities will require that the Department "achieve greater interoperability among systems controls, communications, data products, data links, and payloads/mission equipment packages on unmanned systems including tasking, processing, exploitation, and dissemination."[30] This transformation also requires significant increases in the autonomy of "autonomous" systems.

Understanding the challenges engendered by this revolutionary way of thinking can enable autonomous maritime vehicle developers to design systems that not only reduce the manning on Navy ships directly, but also reduce it indirectly by having constellations of UAVs and UMVs work together seamlessly and provide their own command and control and direction without forcing the operator to intervene every step of the way. But this requires, in Albert Einstein's words, a new way of "figuring out how to think about the problem."[31]

Clearly, a broader incorporation of autonomous maritime systems into the Fleet creates challenges not previously encountered by commanders, decision makers, and legacy structures designed for command and control of humans and groups by humans. Command and control (C2) and networking comprise more than just boxes, beams, and bandwidth. The ways and means by which information is extracted, organized, communicated and employed will be central to how a future commander conducts operations. None of these challenges are impossible to

overcome – indeed they can become opportunities – if and only if UAV and UMV developers keep this end state firmly in mind throughout the development process.

Where "Boots Hit the Ground:" Opportunities For Naval Unmanned Systems

Chief of Naval Operations Admiral Roughead demonstrated his commitment to developing a long-term vision for autonomous systems in 2008, when he directed the 28th U.S. Naval War College Strategic Studies Group (SSG) to spend one year examining this issue. The SSG is tasked by the CNO, and reports directly to him. Its work typically involves year-long projects during which they "generate revolutionary concepts in naval warfare … [focusing] on those concepts that have potential that [the Navy is] not necessarily dealing with at the time."[32] The 28th Strategic Studies Group's (SSG's) theme was officially titled "Integration of Unmanned Systems Into Navy Force Structure," and the group was tasked with developing concepts for autonomous systems' development and operations in the 2020 to 2028 timeframe. The 28th SSG's work on autonomous systems encompassed all of the domains in which the Navy operates, rather than focusing solely on UMVs. The CNO explicitly asked the group to take into account the underwater, surface, air, and space domains as they considered future naval autonomous capabilities and operations.

Admiral Roughead asked the SSG to focus on two areas in particular. First, he stressed the integration of unmanned systems with their manned counterparts. As the Navy's inventory will rely heavily on manned systems for the foreseeable future, it makes sense to examine how autonomous and manned systems will complement each other and work together. Admiral Roughead's second area of focus was on the budgetary feasibility of the group's recommendations; he wanted to ensure that the SSG's work was undertaken in the context of realistic fiscal environment. This concern hearkens back to the point made earlier regarding the high-level emphasis placed on Total Ownership Costs, and the need to reduce autonomous systems' manpower requirements.

Admiral Roughead's choice of the SSG to explore this issue grants insight into his vision on how the Navy should proceed. As he noted last year[33], the SSG operates outside of the normal bureaucratic process, and can therefore provide a fresh perspective on the issues that they study. The CNO clearly recognizes the need (described earlier) to overcome entrenched naval culture in order to fully realize the inherent potential of unmanned systems. At the Brookings Institution, he stated:

> I would also say that as we have moved into this, we have some inertia to overcome … and that's why I tend to rely more on the outside groups like the SSG to inform me in that regard, and it really requires that we do take a new look

> at how we employ and how we use these systems. It's very easy I think as we look at those unmanned capabilities … to have operating concepts and doctrine that really is very grounded in a manned-centric approach, and if we don't break out of those old ways of using and think about new deployment concepts, I'm not sure that the investments that we make will move us that much faster in to the future. We have to break the operating concepts as we apply these unmanned systems.[34]

The SSG's unmanned project wrapped up last year, and Admiral Roughead discussed some of the challenges that will need to be addressed as the Navy integrates unmanned vehicles into its force structure.[35] In response to the organizational issues previously outlined, Admiral Roughead has merged the Navy's directorate of intelligence (N2) and directorate of command, control, and communications (N6) into a single directorate called Information Dominance. He also described technological issues, focusing on networking architecture, improving the capabilities of antennas, and enhancing C2 capabilities to allow one sailor to control multiple systems in an attempt to lower total ownership costs. These areas present significant opportunities for the development of unmanned autonomous systems, but Navy labs have already begun to "answer the call."

One way that the autonomous maritime vehicle community can catch up with the air and ground autonomous communities is to leverage the ongoing work – especially in the area of C4 – currently underway as these systems evolve. One such opportunity, responding to the challenge of manning requirements discussed above, is the current "UV-Sentry" project, a joint developmental effort between the Office of Naval Research and the Marine Corps Warfighting Laboratory.[36] This program enables autonomous command and control and cooperative autonomy of autonomous systems, allowing for automated data fusion into a common operational picture. Thus, rather than have large numbers of operators providing constant input and direction to large numbers of autonomous vehicles, the constellation of autonomous systems with increased intelligence and the ability to adaptively collect and process sensor data into actionable information provides this information to the operator with minimum human intervention.[37]

This effort, and others like it – which support the goals of the Department of Defense *FY2009-2034 Unmanned Systems Integrated Roadmap's* of enabling constellations on autonomous systems to provide their own C4 – must be applied to autonomous aerial and maritime vehicles deployed from naval ships. This is vital to reducing the extent of human operators' engagement in direct, manual control of autonomous vehicles.[38] If this C4 breakthrough is achieved, it may well exceed improvement in UAV, USV and UUV propulsion, payload, stealth and other attributes and unleash the revolutionary changes these autonomous systems can deliver to tomorrow's Navy and especially to the Navy-after-Next.

Grass-Roots Efforts at the Navy Laboratory Level

The Space and Naval Warfare (SPAWAR) Systems Center (SSC) is a Navy working capital laboratory with branches in both San Diego, California and Charleston, North Carolina. The Center has extensive experience in unmanned systems research and development, dating all the way back to undersea applications in the 1960's and expanding into ground and air systems in the 1980's. Today, the Center oversees more than sixty projects relating to unmanned systems. These projects span the land, air, and sea domains, and many of them also focus on C2 systems and system architecture, as well as on providing program support to other agencies.

One example of a groundbreaking unmanned project being developed at SSC is the Multi-robot Operator Control Unit (MOCU). This project directly addresses the CNO's directive to allow one operator to control multiple systems in order to reduce manning costs. MOCU is a graphical operator-control software package that allows simultaneous control of multiple heterogeneous unmanned systems from a single console. It has been designed to address interoperability, standardization, and customization issues by using a modular, scalable, and flexible architecture. To date, this software has been used in over seven platforms, including being integrated into the Navy's Littoral Combat Ship (LCS) program for both the Mine Warfare mission and the Antisubmarine Warfare mission.

A third-generation product, based upon a publish/subscribe architecture[39], is currently under development. This update completely uncouples the human interface from the core management software, thus allowing even more flexibility in user customization of the product.

Another program that addresses Admiral Roughead's message is the Joint Collaborative Technologies Experiment (JCTE). This program is a joint effort conducted by SSC Pacific, the Air Force Research Lab, and the Army Aviation and Missile Research Development and Engineering Center. Its objective is the integration of collaborative technologies that support the teaming of manned and unmanned systems across multiple domains, although it focuses mostly on the air and ground. SSC Pacific's contribution to the project is the development of the Autonomous UAV Mission System (AUMS). The AUMS platform will provide a means of forward staging, launching, recovering, refueling, and re-launching of small vertical-takeoff-and-landing (VTOL) UAVs.[40] The AUMS platform is remarkably flexible; it can be operated from surface or ground vehicles, manned or unmanned, or stand alone in a fixed-site installation.

A third project that SSC is currently developing supports the development of the unmanned surface vehicle (USV). The U.S. Department of Defense and Homeland Security are increasingly interested in the use of USVs for a variety of missions, including Special Warfare force projection and reconnaissance; mine counter measures; port and harbor surveillance and

security; marine hydrographic surveying; and environmental sensing. In order for USVs to fill these roles, however, they must be capable of a relatively high degree of autonomous navigation. SSC Pacific is developing core technologies required for robust USV operation in a real-world environment, primarily focusing on autonomous navigation, obstacle avoidance, and path planning.

Lastly, SSC has been tasked with providing technical assessments and research in support of the UV Sentry project, a joint developmental effort between the Office of Naval Research and the Marine Corps Warfighting Laboratory.[41] As previously discussed, this program enhances the autonomy of autonomous systems. It is described as an autonomous capability for long-term, persistent, and accurate surveillance, detection and engagement of threats that spans large geographical space and media. It incorporates four critical enablers. First, its autonomous C2 systems allow for autonomous mission planning and task allocation between vehicles without centralized control. Second, it enables automated launch, recovery, and sustainment. Third, UV Sentry enables automated fusion of data from distributed, heterogeneous sensors. Lastly, the system enables automated target “discernment,” which allows for the detection of anomalous behavior and the determination of intent. This project represents a game-changing, disruptive technology. It is an innovative response to current and emerging threats that minimizes manpower requirements. As such, it may indicate the direction of unmanned systems’ future research and development.

The Way Ahead

“To change anything in the Navy is like punching a feather bed. You punch it with your right and you punch it with your left until you are finally exhausted, and then you find the damn bed just as it was before you started punching.”[42]

President Theodore Roosevelt

While the future for autonomous vehicles is virtually unlimited and their ability to deliver revolutionary change to the Navy-after-Next and alter the face of naval warfare is real, this process is not without challenges. This vision must be supported by a both a commitment of the top levels of naval leadership and concomitant leadership and stewardship at the programmatic level – from acquisition professionals, to requirements officers, to scientists and engineers in the Navy and industry imagining, designing, developing, modeling, testing, and fielding these systems.

Evolutionary change is good and, in many ways, easy. Revolutionary change in any organization – and especially one with the rich traditions, extensive doctrine, organizational structures, and long-extant business rules of the United States Navy – will not occur without big

bets and a thoughtful degree of risk-taking on the part of professionals embedded in a thoroughly risk-adverse culture.

One sure way to spur this revolutionary change is to operationalize the mandate of the Department of Defense *FY2009-2034 Unmanned Systems Integrated Roadmap's* to; "Expedite the transition of unmanned technologies from research and development activities into the hands of the Warfighter."[43] The American Bluejacket is the Navy's secret weapon in achieving, overcoming, and innovating. Getting a "pretty good" autonomous maritime system into the Fleet today is infinitely better than getting a near-perfect UMV into a Sailor's hands five years from now.

There is no more propitious time to do this. The Secretary of Defense has been widely-quoted as adamantly opposed to seeking the 99% solution that takes years to develop and instead getting the 80% solution into warfighter's hands today.[44] If the Navy follows this mandate, Sailors, Chiefs, and Officers will begin to imagine what a Navy robustly manned with a wide array of autonomous vehicles could accomplish. *That* is where the future vision of autonomous maritime systems will be developed and nurtured.

If the Navy does this right, autonomous vehicles will continue to change the tactics of today's Navy, the operational concepts of tomorrow's Navy, and will usher in a strategic shift for the Navy-after-Next. For these reasons, autonomous vehicles development deserves ongoing enlightened leadership and stewardship and the additional consideration and focus needed to make that Navy the greatest navy that ever sailed.

[1] Max Boot, *War Made New: Technology, Warfare, and the Course of History 1500 to Today* (New York, Gotham Books, 2006). Boot uses historical examples to show how technological-driven "Revolutions in Military Affairs" such as the Gunpowder Revolution, the Industrial Revolution, the Second Industrial Revolution, and the Information Revolution have transformed warfare and altered the course of history.

[2] *Science and Technology for the 21st Century Warfighter* (Washington, D.C., Office of Naval Research, 2004).

[3] *War Made New*. Max Boot does not present technology as the only element determining victory or defeat, giving full acknowledgement to a host of other factors, from geography, to demography, to economics, to culture, to leadership. However, he is firm in his contention of technology's huge impact, noting; "Some analysts may discount the importance of technology in determining the outcome of battles, but there is no denying the central importance of advanced weaponry in the rise of the West….The way to gain military advantage, therefore, is not necessarily to be the first to produce a new tool or weapon. Often it is to figure out better than anyone else how to utilize a widely available tool or weapon."

[4] Bruce Berkowitz, *The New Face of War: How War Will be Fought in the 21st Century* (New York, The Free Press, 2003), pp. 2-3. Berkowitz does not restrict his examples to one conflict, noting further; "The same thing happened when the United States fought Yugoslavia in 1999 and the Taliban regime in Afghanistan in 2001. Each time experts feared the worst; each time U.S. forces won a lopsided victory." But like Boot, he stresses that it is the possession of better technology alone is not enough, saying; "And simply having better technology does not guarantee success. Victory goes to the side that understands how to use technology more effectively." (p. 3)

[5] *Global Trends 2025: A Transformed World* (Washington, D.C., National Intelligence Council, November 2008), p. viii. Accessed at: www.dni.gov.nic/NIC_2025_project.html. See also, *War Made New*, p. 8. Max Boot captures how uncertain this transition is, noting, "Inevitably, there was a lag, ranging from a few decades to a few centuries, between the initial development of a technology and the moment when it transformed the battlefield."

[6] *Joint Operating Environment 2010: Ready For Today, Preparing For Tomorrow* (Suffolk, Virginia, Untied States Joint Forces Command, 2010). Accessed at http://www.jfcom.mil/newslink/storyarchive/2010/JOE_2010_o.pdf. This publication, commonly referred to as "*The JOE*," serves as the "problem statement" regarding what challenges the U.S. military and its coalition partners will face in the future and informs all subsidiary Joint publications, beginning with the *Capstone Concept for Joint Operations*.

[7] Mark Thompson, "Taming the System," *Time*, February 23, 2009. Secretary Gates has been quoted extensively in the defense and national media extolling the U.S. Navy's technological advantage over the navies of any potential adversary.

[8] *Science and Technology for the 21st Century Warfighter*, pp. 1-35.

[9] *A Cooperative Strategy for 21st Century Seapower* (Washington, DC, Department of the Navy, October 2007), pp. 4-5.

[10] *FY 2009-2034 Unmanned Systems Integrated Roadmap* (Washington, D.C., Department of Defense, 2009), p. 7.

[11] *FY 2009-2034 Unmanned Systems Integrated Roadmap* (Washington, D.C., Department of Defense, 2009), p. 3. This document defines UMVs as: "Unmanned undersea vehicles (UUVs) and unmanned surface vehicles (USVs)."

[12] The Honorable Robert Gates, "A Balanced Strategy: Reprogramming the Pentagon for a New Age," *Foreign Affairs*, January/February 2009.

[13] Far from being merely a new defense "buzzword," hybrid warfare has a strong pedigree and has evolved over the past year in a number of articles in respected journals. See also, Michelle Flournoy and Shawn Brimley, "The Defense Inheritance: Challenges and Choices for the Next Pentagon Team," *The Washington Quarterly*, Autumn 2008, and Frank Hoffman, "Hybrid Warfare and Challenges," *Joint Forces Quarterly*, Issue 52, 1st Quarter 2009, for influential articles that Secretary Gates' *Foreign Affairs* article built on. Additionally, and more recently, see Frank Hoffman, "Hybrid Threats: Reconceptualizing the Evolving Character of Modern Conflict," *Strategic Forum*, Number 240 (Washington, D.C., Institute for National Security Studies, National Defense University, April 2009), accessed at: www.ndu.edu/inss. Beyond these articles, read by a small, but select, group, hybrid warfare is gaining increasing currency in the defense and national media. See, for example, "At Onset of QDR, 'Hybrid Warfare,' Term Gains Momentum," *Inside the Pentagon*, February 12, 2009, Sydney Freeberg, "The Military's New Hybrid Warriors," *National Journal*, March 14, 2009, John Donnelly, "Bold Steps but a Well-Worn Path," *CQ Weekly*, p. 1084, May 11, 2009, and Matthew Jones, "Expert's Vision of Future Warfare is Not Black and White," *Norfolk Virginia Pilot*, May 13, 2009.

[14] As the new Undersecretary of Defense for Policy, Ms. Flournoy is in an especially key position to support Secretary Gates' initiative to field a U.S. military able to simultaneously deal with conventional and irregular tactics.

And the focus on hybrid warfare goes beyond OSD policy circles, to the highest levels of the uniformed services, with Chairman of the Joint Chiefs of Staff, Admiral Michael Mullen, noting in the *Capstone Concept for Joint Operations*, "These clean distinctions between conventional and irregular warfare will rarely exist in reality; however, as often in the past, future conflicts will appear as hybrids comprising diverse, dynamic, and simultaneous combinations of organizations, technologies, and techniques that defy categorization (*Capstone Concept for Joint Operations* (Washington, DC, The Joint Staff, January 2009))."

[15] Defense Budget Recommendation Statement (Arlington, VA) As Prepared for Delivery by Secretary of Defense Robert Gates, Arlington, VA, Monday, April 6, 2009, accessed at: www.defenselink.mil/speeches/speech.aspx?speechid=1341>.

[16] The full Fiscal Year 2010 Department of Defense Budget is most conveniently summarized in a six-page "2010 Budget Proposal" prose summary and a four-page "FY10 Budget Request" slide summary, both accessed at: www.defense.link.com.

[17] *FY 2009-2034 Unmanned Systems Integrated Roadmap* (Washington, D.C., Department of Defense, 2009), p. 4.

[18]See, for example, Naval Research Advisory Committee (NRAC) report, *Roles of Unmanned Vehicles*, March 2003, accessed at: www.onr.navy.mil/nrac. This 2003 NRAC report recognized the importance of unmanned systems in conflicts *six years ago*, noting: "Increasing demands upon operating forces in terms of tempo, increased threat capabilities, rules of engagement parameters and risk management are leading Naval Forces, as well as other services, to the development and reliance on such systems." See also, Naval Studies Board, N.R.C., *Autonomous Vehicles in Support of Naval Operations*, The National Academies Press, Washington, D.C., 2005.

[19] *FY 2009-2034 Unmanned Systems Integrated Roadmap* (Washington, D.C., Department of Defense, 2009), p. xiii.

[20] See, P.W. Singer, "Wired for War? Robots and Military Doctrine," *Joint Forces Quarterly*, Issue 52, 1st Quarter 2009. This article highlighted the astounding "ramp up" in air and ground unmanned systems used in Operation Iraqi Freedom, (while not mentioning unmanned maritime vehicles) noting: "When U.S. forces went into Iraq with only a handful of drones in the air (all of V Crops had just one), by the end of 2008, there were 5,331 unmanned aircraft systems in the American inventory, from vigilant Global Hawks to armed Predators that circle thousands of feet overhead to tiny Ravens that peer over the next city block. A similar explosion happened on the ground where zero unmanned ground vehicles were used in a tactical sense during the 2003 invasion; by the end of 2008, the overall inventory crossed the 12,000 mark, with the first generation of armed ground robotics arriving that year as well." This article and others like it, by pointing out the massive use of unmanned air and ground vehicles in combat, all-but-ensure that these systems (as opposed to unmanned maritime systems) continue to receive the lion's share of attention (and funding).

[21] The astounding – and widely reported – success of unmanned aerial systems in Iraq has set up what some defense commentators refer to as a "virtuous cycle" with success begetting further success – and recognition – at the highest levels of the Navy as well as Congress. See, for example, *Statement of Admiral Gary Roughead, Chief of Naval Operations, before the House Armed Services Committee on the FY10 Department of the Navy Posture*, 14 May 2009, pp. 1-19. In two sections of his prepared testimony where he talks about "Building Tomorrow's Navy," the CNO talks at some length about procuring unmanned aircraft systems, while no mention is made of unmanned maritime vehicles anywhere in his 19-page testimony.

[22] *Program Executive Office, Littoral & Mine Warfare Annual Report FY 2008*. The seven program offices under the purview of PEO LMW include: PMS340, Naval Special Warfare (SEALS); PMS403, Unmanned Maritime Vehicles; PMS408, Explosive Ordnance Disposal/Joint Counter Radio Controlled Improvised Explosive Device Electronic Warfare (EOD/CREW); PMS420, LCS Mission Module; PMS480, Anti-Terrorism/Force Protection; PMS485, Maritime Surveillance; and PMS495, Mine Warfare.

[23] Barack Obama, "Renewing America's Leadership." *Foreign Affairs*, July/August 2007.

[24] *Roles of Unmanned Vehicles*, March 2003.

[25] *FY 2009-2034 Unmanned Systems Integrated Roadmap*, pp. 39-41.

[26] "Chief Concerns: Interview with CNO Mullen," *Government Executive*, May 2006.

[27] Patricia Hamburger, Robert Bost and Jennifer McKneely, "Optimized Crewing for Surface Ships," accessed at: www.manningaffordability.com. It is important to note that there are additional benefits to pursuing optimized crewing on Navy ships beyond the cost avoidance and cost savings related to reducing the numbers of sailors on Navy ships. Improved operational capability, morale, efficiency, and effectiveness, as well as reduction in errors and programmatic and schedule risks are all valid measures of meaningful return on investments. The rapidly increasing costs of military manpower is the subject of articles in the defense and mainstream press. See for example, Jim Arkedis, "America's Costliest Weapon," *San Diego Union Tribune*, April 27, 2009. The author cites the "astonishing" cost of military manpower, of $160,000 per person, per year. See also, John Donnelly, "Bold

Steps but a Well-Worn Path," *CQ Weekly*, p. 1084, May 11, 2009. The author cites a 2007 report by the Government Accountability Office noting; "…the cost of each soldier in 2006 stood at about $126,000 a year. That figure has risen since then with the increasing cost of health care and the length of foreign deployments."

[28] The Navy has been "studying" ways to reduce manpower on ships for well over a decade. One of the most significant ways the Navy has learned "best practices" has been through the efforts of the Naval Research Advisory Committee (NRAC), which issued its first report on naval ship manpower in 1995. See for example, Robert Spindel at al, *Naval Research Advisory Committee Report: Optimized Ship Manning, April 2000* (Washington, D.C. Office of the Assistant Secretary of the Navy for Research, Development and Acquisition, 2000) for a comprehensive analysis of manpower and total ownership costs. See also, "Ten Questions: An Interview with Patricia S. Hamburger, Director, Human Systems Integration, Naval Sea Systems Command (NAVSEA)," pp. 15-21 and Alexander Landsburg et al, "The Art of Successfully Applying Human Systems Integration," pp. 77-107, both in *Naval Engineers Journal*, Vol. 120, No. 1, 2008; Glenn Osga et al, "'Task-Managed' Watchstanding: Providing Decision Support for Multi-Task Naval Operations," Space and Naval Warfare Systems Center San Diego *Biennial Review*, *2001*, pp. 176- 185; George Galdorisi and Glenn Osga, "Human Factors Engineering: An Enabler for Military Transformation Through Effective Integration of Technology and Personnel, Space and Naval Warfare Systems Center San Diego *Biennial Review*, *2003*;" Kelly Abruzzo et al, "Human Systems Integration: The Key to Achieving a U.S. Navy of 313 Ships Through the Effective Integration of Technology, Personnel, and Training," in *Proceedings of the 2009 Human Systems Integration Symposium*; Robert Bost and George Galdorisi, "Transforming Coalition Naval Operations by Using Human Systems Integration to Reduce Warship Manning: Lessons Learned from the United States Navy DDG 51 Class Warship Reduced Manning Study," published in *The Proceedings of the Ninth International Command and Control Research and Technology Symposium*, September 2004.

[29] Phillip Ewing, "CNO: Reducing Crew Sizes a Top Priority," *Navy Times*, March 27, 2008. See also Geoff Fein, "DDG-1000: Bigger Ship, Smaller Crew," *Defense Daily*, April 8, 2008. The cultural issues Admiral Roughead refers to are difficult to overstate and have been the subject of professional discourse within the Navy for over a decade-and-a-half. See, for example, J. Robert Bost, James G. Mellis and Philip A. Dent, "Is the Navy Serious About Reducing Manning on Its Ships?" *Proceedings of the Association of Scientists and Engineers (ASE) Symposium, April 13, 1994*, accessed at: www.manningaffordibility.com. The study's authors make a persuasive argument that, "the greatest obstacle to reducing manpower on Navy ships is the resistance to change in U.S. Navy tradition which results in outmoded technology paradigms and organizational culture;" Tom Bush, J. Robert Bost, Trish Hamburger, and Thomas Malone, "Optimizing Manning on DD-21," *Proceedings of the Association of Scientists and Engineers (ASE) 36th Annual Technical Symposium*, April 23, 1999. The authors point out how, for the then-DD 21 Program, the optimized manpower strategy began with an assumed manpower level of zero and how all manpower levels had to be justified by a top-down functional level analysis; and Greg Maxwell and J. Robert Bost, "The Navy Must Put People First," *U.S. Naval Institute Proceedings*, March 2004, pp. 90-92.

[30] *FY 2009-2034 Unmanned Systems Integrated Roadmap*, p. 35.

[31] When asked what single event was most helpful in developing the theory of relativity, Albert Einstein is reported to have answered, 'Figuring out how to think about the problem." Wilber Shramm and William Porter, Men, *Women, Messages and Media: Understanding Human Communication* (New York, Harper and Rowe, 1982).

[32] The Brookings Institution. Proceedings, The Future of Unmanned Naval Technologies: A Discussion with Admiral Gary Roughead, Chief of Naval Operations, 2 November 2009, Washington, D.C. Accessed online 25 Jan. 2010 <http://www.cffc.navy.mil/unmanned_technologies_adm_roughead.pdf>.

[33] Ibid.

[34] Ibid.

[35] Ibid.

[36] See, for example, Michael Fetsch, Chris Mailey, and Sara Wallace, "UV Sentry," paper presented at the *Association for Unmanned Vehicle Systems International, 34th Annual Symposium and Exhibition*, Washington, DC, August 6-9, 2007; Ryan Kilgore et al, "Mission Planning and Monitoring for Heterogeneous Unmanned Vehicle Teams: A Human Centered Perspective," paper presented at the *American Institute of Aeronautics and Astronautics Conference*, Rohnert, California, May 7-10, 2007; C.E. Nehme et al, "Generating Requirements for Futuristic Heterogeneous Unmanned Systems," *Proceedings of the 50th Annual Meeting of the Human Factors and Ergonomics Society*, San Francisco, California, 2006; and P.W. Singer, "Wired for War? Robots and Military Doctrine,"

[37] Thomas McKenna, (Office of Naval Research, Code 341) "Future Capabilities: Perception, Understanding and Intelligent Decision Making," briefing presented at the Autonomous Systems Innovation Summit, Arlington, Virginia, November 17-18, 2008.

[38] Ryan Kilgore et al, "Mission Planning and Monitoring for Heterogeneous Unmanned Vehicle Teams: A Human Centered Perspective, pp. 1-2."

[39] The Air Force Research Laboratory's Information Directorate is working with SPAWAR to develop these Publish-Subscribe-Query-Broker technologies.

[40] Mullens, K., Burmeister, A., Wills, M., Stroumsto, N., Denewiler, T., Pachura, J., Prior, G., and B. Hawkins, "Automated Launch, Landing and Refueling Technologies for Increased UGV-UAV Effectiveness," International Joint Topic: 9th Emergency Preparedness and Response/11th Robotics and Remote Systems for Hazardous Environments, Salt Lake City, Utah, February 12-15, 2006.

[41] See, for example, Michael Fetsch, Chris Mailey, and Sara Wallace, "UV Sentry," paper presented at the *Association for Unmanned Vehicle Systems International, 34th Annual Symposium and Exhibition*, Washington, DC, August 6-9, 2007; Ryan Kilgore et al, "Mission Planning and Monitoring for Heterogeneous Unmanned Vehicle Teams: A Human Centered Perspective," paper presented at the *American Institute of Aeronautics and Astronautics Conference*, Rohnert, California, May 7-10, 2007; C.E. Nehme et al, "Generating Requirements for Futuristic Heterogeneous Unmanned Systems," *Proceedings of the 50th Annual Meeting of the Human Factors and Ergonomics Society*, San Francisco, California, 2006; and P.W. Singer, "Wired for War? Robots and Military Doctrine,"

[42] Attributed to President Theodore Roosevelt.

[43] *FY 2009-2034 Unmanned Systems Integrated Roadmap*, p. 34.

[44] Secretary of Defense Robert Gates has made this point repeatedly in speeches and interviews. One of the most widely quoted speeches on this subject were his remarks at the Army War College on April 16, 2009 when he noted; "Finally, I concluded we needed to shift away from the 99% exquisite service-centric platforms that are so costly and so complex they take forever to build and only then in very limited quantities. With the pace of technological and geopolitical change and the range of possible contingencies, we just look more to the 80-percent solution, the multi-service solution that can be produced on time, on budget and in significant numbers. As Stalin once said, "Quantity has a quality all of its own."